Amendments to the Specification

Please amend the specification as follows:

Please replace the paragraph at page 1, line 22, to page 2, line 4, according to the following:

In general, the performance of lithograph projection systems is limited because of aberrations, which are the deviation of a projection lens' performance from a "perfect" lens or from the diffraction limit. As the resolution required from lithography projection systems increases, for example as low as 100nm and below, the ability to measure the state of the optical aberration of ~~project~~ projection lenses becomes increasingly important. For example, aberrations as small as 10 milliwave ($m\lambda$) or less can cause significant shifts and distortions in patterns.

Please replace the paragraphs at page 5, line 9, to page 6, line 18, according to the following:

DETAILED DESCRIPTION

Methods of in-situ interferometry are described in U.S. Pat. No. ~~5,3828,455~~ 5,828,455 entitled "Apparatus, Method of Measurement, and Method of Data Analysis for Correction of Optical System" issued Oct. 27, 1998, to Smith et al.; and U.S. Pat. No. 5,978,085 *entitled* "Apparatus Method of Measurement, and Method of Data Analysis for Correction of Optical System" issued Nov. 2, 1999 to Smith et al., both of which are incorporated by reference herein in their entirety.

The two patents referenced above describe an in-situ interferometer that includes an image matching optic, an encoded face (EF), and an aperture plate (AP). The image matching optic increases the diversity of ray angles impinging on the encoded face so as to fill an entrance pupil of the lithographic projection system imaging objective (IO). The EF provides structures (typically at the reticle object plane) that are imaged onto a wafer and subsequently ~~positionaly~~ positionally measured. The AP restricts the size of the individual ray bundles and thus determines the wave front reconstruction resolution. While this in-situ interferometer

is effective, it would be advantageous to reduce its complexity and the number of components that are needed.

Figure 1 illustrates a system that can implement the technique described in the two Smith patents (U.S. Pat. No. ~~5,3828,455~~ 5,828,455 and U.S. Pat. No. 5,978,085). Figure 1 is a block diagram illustrating a projection system 100. Figure 1 schematically illustrates how information about aberrations are obtainable. Point P 104 in the reticle plane 103 has an aperture plate AP 108 interposed between it and the first element of the optical system. Of the rays 1, 2, 3, 4, 5 emitted from P, only ray 4 passes through the opening O 106 in the aperture plate AP 108, so that ray 4 is transmitted by the IO 102 and projected onto a wafer in image plane 112. Aberrations of the imaging objective 102 cause ray 4 to deviate (drawn as a dashed line) from the path that an unaberrated image objective would produce (drawn as a solid line). The aberrations cause the ray to intersect the wafer plane at a transverse position PI 110 differing from intersecting position for an imaging objective without aberrations (a "perfect" imaging objective) by an amount proportional to grad(Φ(u)). At the reticle, nearby point P' has only a small bundle of rays centered on ray 1' passing through the aperture O 106 in the aperture plate AP 108, through imaging objective 102, and intersecting the image plane 112 at the point P'I 110'. The deviation of ray 1' from its ideal imaging point is also proportional to grad(Φ(u')), u' being the angle or position of ray 1' as it passes through the aperture stop AS (see solid line (unaberrated) and dashed line (aberrated)).

Please replace the paragraph at page 8, line 3-12, according to the following:

Figure 3 is a diagram illustrating the appearance of the effective source (ES) 204 at the conjugate aperture stop (CAS) 216 and aperture stop (AS) 232 if the illumination modifying optic (IM) 214 is removed, see Figure 2. The lens (L) 206 pupil (P) 304 is the image of the aperture stop in the object space. Because the aperture of the system limits the size of the axial cone of energy that will pass through the optical system, the lens pupil determines the amount of energy accepted

by and emitted from the optical system. The maximum cone angle of light accepted or emitted by an optical system is expressed as its numerical aperture. The hatched region 302 illustrates the effective source (ES) with source numerical aperture NAs. As shown in Figure [[3A]] 3 the effective source (ES) numerical aperture NAs lies within lens pupil (P) 304 which has numerical aperture NA.

Please replace the paragraph at page 9, lines 7-13, according to the following:

Figure 5 illustrates the numerical aperture S' 330 of the effective source ES after the opaque disk 310, being used as illumination modifying optic 214, has been placed at the CAS 216. As discussed in Figure 4, positioning the opaque disk 310 at the CAS [[214]] 216, see Figure 2, reduces the numerical aperture NAs of the effective source ES (204). Thus, light emitted from the effective source ES and incident on lens (L) 206, see Figure 2, has a reduced numerical aperture in accordance with the size of the hole 312 in the disk 310, that is being used in this example, as image modifying optic (IM) 214.

Please replace the paragraphs at page 9, line 21, to, page 10, line 13, according to the following:

As shown in Figure 2, a chief ray C1 and marginal rays RMA and RMB are shown incident on a measurement fiducial M1. Referring to Figure 5, the chief ray C1 is the center of the entire ray bundle emanating from the effective source (ES) 204 and incident on fiducial M1, while RMA and RMB are representative marginal rays, or rays that are on the edge of the effective source (ES) 204 with numerical aperture NAs. Fiducial M1 is located on the optical axis of the lens (L) 206 and thus the chief ray C1 emerges from the lens 206 perpendicular to the encoded face (EF) 224 of the reticle 208. A different chief ray C2 is incident on the measurement fiducial M2, and because it is not incident on the optical axis of lens 206 but is at a displacement h from the optical axis (h = distance between fiducials M1 and M2) it

emerges from the encoded face (EF) of the reticle 208 at an angle q from perpendicular. The angle q, in a paraxial approximation, is equal to:

$$q = h / f \qquad \text{(Eq. 2)}$$

[[Where]] where f is the focal length of the lens (L) 206. Referring to Figure 5, in the pupil (P) 304 the chief ray C2 that emerges from the encoded face (EF) 224 of the reticle 208 is centered on an effective source S" region 334 as a result of the lens bending action and the angular offset from the chief ray C1 that emerged perpendicular to the encoded face (EF) 224 of the reticle 208 as approximated by Equation 2.

Please replace the paragraph at page 16, line 6 through line 9, according to the following:

Another measurement technique utilizes an electronic detector (either integral of, or detachable from, the lithography tool) capable of measuring the spacing between the projected fiducials either one at a time or in parallel. Such a system could utilize a reference array (MO) measurement.

Please replace the paragraphs at page 16, line 11 through page 17, line 9, according to the following:

Ray bundles S', S" (Figure 5) sample very different portions of the lens (L) 206 and are deviated at the sensor plane SP (Figure 2) from their ideal positions (equal to position on encoded face/magnification) by lens aberrations in the manner described in Smith et al., U.S. Patent No. 5,828,455 (herein incorporated by reference). The projected deviations due to the lens aberrations is given by Equation 4:

$$(dx,dy)=(\lambda/2\pi NAi) * \int d^2nW(n)\nabla(\phi(n)) / \int d^2nW(n) \qquad \text{(Eq 4)}$$

where:

[[1]] λ = wavelength of light from the effective source ES

[[Nai]] NAi = numerical aperture on the image side = M*NA

N = transverse (nx,ny) direction cosine vector for position in exit pupil

W(n) = I(n) = intensity of effective source after passing through IMO = (for example) intensity of S' or S" for measurement fiducials M1 and M2 respectively

$\phi(n)$ = optical aberration of the projection lithographic tool.

For the projected measurement fiducial M1', I(n) is > 0 over the region S' of Figure [[3C]] 5 so that the influence of the aberrations is just the weighted slope of grad ($\phi(n)$) over this area of the pupil. Thus as discussed in the two Smith patents referenced above, taking positional or differential offset measurements at an array of positions for the projected measurement fiducials, we can reconstruct the imaging [[of]] objective (IO of Figure 2) aberration. See also, "Method of Zernike Coefficients Extraction for Optics Aberration Measurement" by T. Shiode, S. Okada, H. Takamori, H. Matsuda and S. Fujiware[[;]], SPIE Conference on Metrology, Inspection, and Process Control for Microlithography, March 2002, incorporated by reference herein in its entirety.

Please replace the paragraphs at page 17, line 11 through page 18, line 2, according to the following:

Figures 11A-11C and 4 illustrate a device capable of carrying out aspects of the invention. Figure 11A shows in side view a unit reticle 902 with three optical elements illustrated as lenses (L1, L2, L3), 904, 906, and 908, respectively, attached. Optical elements 904, 906, and 908 can be, for example, refractive lenses, conical lenses, diffractive optics, compound lenses or any combination of types of optical elements.

Figure 11B shows in [[plan]] planar view, nine measurement fiducial arrays or field points (FP1, ... FP9) 922-938. Each field point is associated with a corresponding lens (not shown). Figure 11C illustrates an example of a reticle 902 with a reference array (MO). As shown in Figure 11C, the reticle includes a reference array (MO) with nine field points and corresponding complementary fiducials associated with each field point. This reticle does not have lenses attached. Nine field points are shown for ~~purpose~~ purposes of illustration only, it should be understood that any desired number of field points may be used in

accordance with a desired lens packing density and the desired transverse size at each field point. Figure [[3B]] 4 shows the image modifying optic, IM1, that is inserted into the effective source ES.

Please replace the paragraphs at page 18, line 4 through line 24, according to the following:

Equation 2 above describes the chief ray angle q as a function of image height. This is true only in the paraxial approximation. A more exact analysis can account for the exact ray tracing through the lens (L) ~~into account~~. In the exact analysis, the ray angle is expressed by a formula ~~in the form~~:

$$\mathrm{Sin}(q) = a1*x+a2*x^2+a3*x^3+ \ldots \qquad \text{(Eq. 5)}$$

Where the coefficients a1, a2, ... are functions of the lens geometry. In practice, this ~~formulation~~ formula is generally used.

Optical elements that can be used in place of a lens include conical or axicon optics, compound (multiple) lenses, diffractive optics, and reflective optics. Especially in the case of reflective optics, the optical element can be detached from the reticle that includes the encoded face and mounted in the projection imaging tool as a separate subsystem. This may be desirable in X-ray or EUV systems utilizing all reflective optics.

The image modifying optic IM (see Figure 2) can be a diffractive optical element. In that case, it will be located at a plane other than CAS and will act to efficiently shape the source.

In another variation, the optical element can be replaced by a pinhole or small clear opening above the encoded face. Then rather than decreasing the size of the effective source, an image modifying optic IM that increases the size of the sources S' and S" to overfill pupil P ~~issued~~ is used. A diffuser is an example of such an IM. The optical element (pinhole) then restricts the ray bundle diameter incident and defines the chief ray angle incident on each measurement fiducial on EF.

Please replace the Abstract at page 28, lines 5-9, according to the following:

An in-situ interferometer includes an image modifying optic that ~~produced~~ produces light ray bundles. The light ray bundles are projected onto a reticle with a plurality of measurement ~~fiducial~~ fiducials encoded onto a face of the reticle. The measurement ~~fiducial~~ fiducials are exposed onto a sensing plane and their locations measured. Aberrations in the projection system are determined from the measurements of the exposed reticles.

Amendments to the Claims

This listing of claims will replace all prior versions, and listings, of the claims in the application:

Listing of the Claims:

1. (original) A method of in-situ measurement of optical aberrations, the method comprising:

producing an illumination source at low partial coherence and chief rays overfilling an entrance pupil;

exposing measurement fiducials of an encoded face of an optical element onto a sensing plane;

measuring relative positions of the exposed measurement fiducials on the sensing plane; and

determining the optical aberration from the measured positions and known relative positions of the measurement fiducials of the encoded face.

2. (original) A method as defined in Claim 1, wherein the optical element is a refractive lens.

3. (original) A method as defined in Claim 1, wherein the optical element is a conical lens.

4. (original) A method as defined in Claim 1, wherein the optical element is a diffractive optic.

5. (original) A method as defined in Claim 1, wherein the optical element is a compound lens.

6. (original) A method as defined in Claim 1, wherein the optical element is an aperture.

7. (original) A method as defined in Claim 1, wherein the measurement fiducials are scanner wafer alignment marks.

8. (original) A method as defined in Claim 1, wherein the measurement fiducials are stepper wafer alignment marks.

9. (currently amended) A method as defined in Claim 1, wherein the measurement fiducials are square toruses.

10. (original) A method as defined in Claim 1, wherein the measurement fiducials are crosses.

11. (original) A method as defined in Claim 1, wherein the measurement fiducials include subresolution features to thereby produce a gradient in transmission.

12. (original) A method as defined in Claim 1, wherein producing a light source at low partial coherence further comprises providing an illumination modifying optic.

13. (original) A method as defined in Claim 12, wherein the illumination modifying optic is an opaque disk with a hole in it wherein the illumination modifying optic is placed at the conjugate aperture stop of a projection lithography tool.

14. (original) A method as defined in Claim 12, wherein the Illumination modifying optic is a diffuser.

15. (original) A method of measuring lens aberrations of a projection lens system, the method comprising:

directing a plurality of light ray bundles, each light ray bundle includes a chief ray, onto a plurality of locations on a reticle with a plurality of measurement fiducials

encoded onto a face of the reticle, wherein the chief ray angles incident at the plurality of locations on the reticle differ;

exposing the plurality of measurement fiducials through a lens and onto a sensing plane;

measuring positions of the plurality of exposed measurement fiducials on the sensing plane; and

determining aberrations of the exposed measurement fiducials.

16. (currently amended) A method as defined in Claim 15, wherein producing a plurality of light ray bundles at desired locations further comprises:

inserting an illumination modifying optic between a light source and a condensing lens thereby forming an effective source, wherein the illumination modifying optic is located at a conjugate aperture stop of an image plane of the projection lens system, wherein light passing through the illumination modifying optic and condensing lens forms a plurality of light ray bundles with corresponding chief rays; and

placing an optical element between the effective source and an encoded face, wherein angles of ~~incident~~ incidence of the chief rays within the respective bundles vary sufficiently to overfill a pupil of the optical element.

17. (original) A method as defined in Claim 16, wherein the optical element is a lens.

18. (original) An illumination source comprising:

a light source;

a condensing lens configured to accept light from the light source;

an illumination modifying optic between the light source and the condensing lens, wherein the illumination modifying optic is located at a conjugate aperture stop of an image plane of a projection lens system, wherein the illumination modifying optic is configured such that light from the light source that passes through the

illumination modifying optic and condensing lens forms a plurality of light ray bundles with corresponding chief rays; and

placing a lens on a side of the condensing lens opposite from the illumination modifying optic, wherein angles of incidence of the chief rays within the respective light ray bundles onto the lens vary sufficiently to overfill the lens pupil.

19. (original) An illumination source as defined in Claim 18, wherein the illumination modifying optic comprise an opaque disk with a hole in it.

20. (original) An illumination source as defined in Claim 18, wherein the illumination modifying optic is a diffuser.

21.(original) A method as defined in Claim 18, wherein the lens is a refractive lens.

22. (original) A method as defined in Claim 18, wherein the lens is a conical lens.

23. (original) A method as defined in Claim 18, wherein the lens is a diffractive optic.

24. (original) A method as defined in Claim 18, wherein the lens is a compound lens.

25. (original) An effective light source comprising:

a light source;

a condensing lens configured to accept light from the light source; and

an illumination modifying optic between the light source and the condensing lens, wherein the illumination modifying optic is located at a conjugate aperture stop of an image plane of a projection lens system, and the illumination modifying optic is configured such that light from the light source that passes through the illumination modifying optic and condensing lens forms a plurality of light ray bundles with corresponding chief rays.

26. (original) An illumination source as defined in Claim 25, wherein the illumination modifying optic comprise an opaque disk with a hole in it.

27. (original) An illumination source as defined in Claim 25, wherein the illumination modifying optic is a diffuser.

28. (original) A reticle comprising:

an array of field points, wherein each field point comprises an array of fiducials; and

an array of optical elements, wherein an optical element is associated with each of the field points.

29. (original) A reticle as defined in Claim 28, wherein the optical element is a refractive lens.

30. (original) A reticle as defined in Claim 28, wherein the optical element is a conical lens.

31. (original) A reticle as defined in Claim 28, wherein the optical element is a diffractive optic.

32. (original) A reticle as defined in Claim 28, wherein the optical element is a compound lens.

33. (original) A reticle as defined in Claim 28, wherein the fiducials are scanner wafer alignment marks.

34. (original) A reticle as defined in Claim 28, wherein the fiducials are stepper wafer alignment marks.

35. (original) A reticle as defined in Claim 28, wherein the fiducials are square toruses.

36. (original) A reticle as defined in Claim 28, wherein the fiducials are crosses.

37. (original) A reticle as defined in Claim 28, wherein the fiducials include subresolution features to thereby produce a gradient in transmission.

38. (currently amended) A projection lithography tool comprising:

an effective light source comprising

a light source;

a condensing lens ~~configure~~ configured to accept light from the light source; and

an illumination modifying optic between the light source and the condensing lens, wherein the illumination modifying optic is located at a conjugate aperture stop of an image plane of a projection lens system, the illumination modifying optic is configured such that light from the light source that passes through the illumination modifying optic and the condensing lens forms a plurality of light ray bundles with corresponding chief rays;

a reticle upon which the light ray bundles are projected, the reticle comprising:

an array of field points, wherein each field point comprises an array of measurement fiducials; and

an array of optical elements , wherein anoptical element is associated with each of the field points; and

an upper lens group wherein the conjugate aperture stop is imaged by the combination of the condenser lens and the upper lens group onto an aperture stop, the upper lens group further including optics to image the measurement fiducials onto a sensing plane.

39. (original) A projection lithography tool as defined in Claim 38, wherein the optical element is a refractive lens.

40. (original) A projection lithography tool as defined in Claim 38, wherein the optical element is a conical lens.

41. (original) A projection lithography tool as defined in Claim 38, wherein the optical element is a diffractive optic.

42. (original) A projection lithography tool as defined in Claim 38, wherein the optical element is a compound lens.

43. (original) A projection lithography tool as defined in Claim 38, wherein the measurement fiducials are scanner wafer alignment marks.

44. (original) A projection lithography tool as defined in Claim 38, wherein the measurement fiducials are stepper wafer alignment marks.

45. (original) A projection lithography tool as defined in Claim 38, wherein the measurement fiducials are square toruses.

46. (original) A projection lithography tool as defined in Claim 38, wherein the measurement fiducials are crosses.

47. (original) A projection lithography tool as defined in Claim 38, wherein the measurement fiducials include subresolution features to thereby produce a gradient in transmission.

48. (original) A projection lithography tool as defined in Claim 38, wherein the illumination modifying optic is an opaque disk with a hole in it.

49. (original) A projection lithography tool as defined in Claim 38, wherein the illumination modifying optic is a diffuser.

<u>Amendments to the Drawings:</u>

Please amend the drawings according to the attached figures, on which the amendments are indicated in red ink. The replacement drawings (Figures 1 through 11C) provided herewith are formal drawings, therefore these drawings are of better quality than those originally filed. In Figure 1, an extraneous comma has been deleted and the drawing reference number "110" associated with point P'l has been replaced with -110'- for clarity. In Figure 4, the drawing reference number "312" has been repositioned at the center of the disk for accuracy. In addition, the margins of the Figures have been modified in accordance with formal PTO parameters. No new matter has been added.

Attachment: Replacement Drawing Sheets

Annotated Sheets Showing Drawing Changes

REMARKS

Any fees that may be due in connection with this application throughout its pendency may be charged to Deposit Account No. 50-1213.

Attached to this Preliminary Amendment are replacement drawings for Figures 1 through 11C. The amendment to Figure 1 deletes an extraneous comma between the drawing reference number "106" and the aperture "O" for clarity. The amendment also changes the drawing reference number referring to point P'1 from "110" to "110' " for clarity. The amendment to Figure 4 repositions the drawing reference number 312 (the hole) at the center of the opaque disk for clarity. Applicant notes that corrected Formal Drawings incorporating these amendments are being submitted under separate cover concurrently with this Amendment. No new matter has been added.

The specification and claims are amended to correct obvious typographical and grammatical errors. In addition, the specification has been amended to include the reference designators 110 and 110'. No new matter has been added to the application.

In view of the amendments and above remarks, entry of the amendments and examination of the application on the merits are respectfully requested.

Respectfully submitted,
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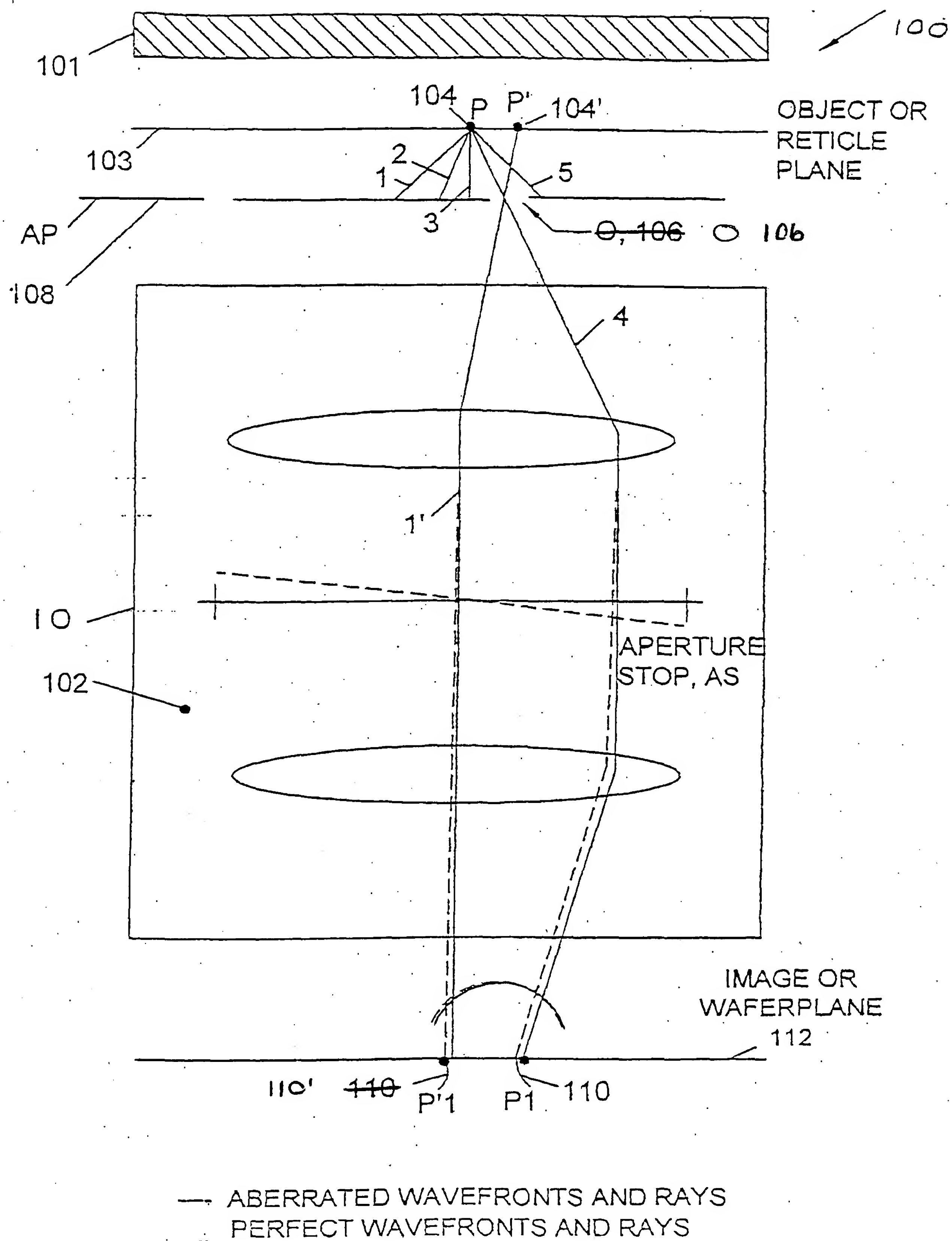

Figure 1

(PRIOR ART)

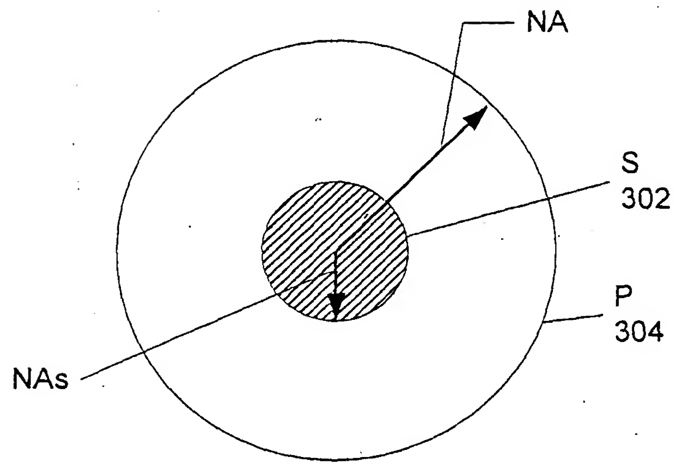

FIGURE 3

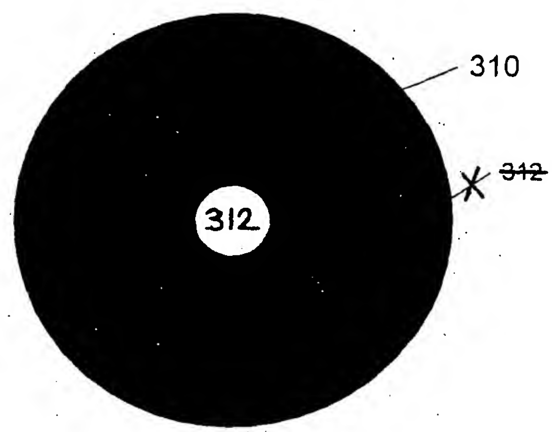

FIGURE 4

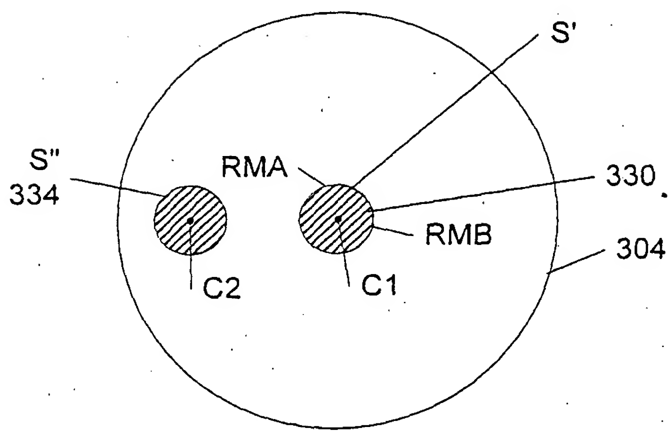

FIGURE 5